AD 718590

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Materiel Test Procedure 6-1-001
Electronic Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

TESTING COMMUNICATION, SURVEILLANCE AND AVIONIC ELECTRONIC EQUIPMENT

1. INTRODUCTION

Testing of Communication, Surveillance and Avionic Electronic Equipment is conducted to determine whether the equipment meets its design specifications and is satisfactory for its intended use. All equipments are subjected to three categories of tests, Engineering, Service, and Environmental tests. Within each of these categories of tests, equipments are operated at various levels and in combination with other equipments (in subsystem or system groups), and are subjected to a full range of operational and environmental conditions.

The basic objectives, preparation, instrumentation techniques and methodology employed in developing these tests are discussed in the following sections.

2. GENERAL CONSIDERATIONS

The approach to any development test inherently involves the questions of what data shall be obtained and how shall they be obtained to permit an effective evaluation of equipment.

Where characteristics and criteria are provided in standard documents such as QMR's and SDR's, the required data may be evident or may be derived. When standards are not provided an operational analysis of the equipment is necessary to establish the significant characteristics and variables related to equipment performance and integrity. Once these are established, methods of obtaining data related to these characteristics and variables must be selected. An example of the establishment of significant system test parameters through operational analysis is given in Appendix A.

The general methods of data collection include the following:

a. Instrumentation and simulation
b. Checklists
c. Interviews
d. Direct observations

Development tests are planned for a complete evaluation of the equipment or system. Previous valid test data which are available are utilized to the extent possible and duplication of test effort is avoided when possible.

Use of uniform testing procedures, as provided by the USATECOM Materiel Test Procedures is encouraged to insure comparable test data with past and future tests. The scope and purpose of the USATECOM Materiel Test Procedures are discussed in section 8.

3. ENGINEERING TEST

The purpose of engineering test is to obtain sufficient information to permit a technical evaluation and a determination of the following:

a. Degree to which the technical performance of the equipment meets the requirements of the Qualitative Materiel Requirement (QMR), Small Development Requirement (SDR), Technical Characteristics (TC), and design requirements.

b. Relative safety of the equipment.

c. Technical and maintenance suitability of the equipment for service test.

Data from an engineering test is also used in further development of equipment.

The approach employed in engineering test of electronic equipment is basically an engineering approach which includes the planning for technical performance and safety data collection. The test is characterized by controlled conditions and elimination of errors in human judgment as far as possible through the utilization of laboratory equipment and techniques, statistical methodology, and personnel trained in engineering or scientific fields.

Laboratory and instrumented field tests are the primary methods for obtaining technical performance data. Where field tests are employed, the same field locations should be used for similar tests, as far as possible to insure comparable results.

For electronic equipment which comprises a system including untested components, a sequence of engineering test phases is required as follows:

a. Component test
b. Intercomponent compatibility of subsystem interface test
c. Subsystem test
d. System test

The scope and objective of each test phase must be defined and their interdependence clearly established.

Unfortunately, the word system has many colloquial meanings, some of which have no place in engineering testing. To exclude such meanings, the following definition is stated:

A system is a set of objects with relationships between the objects and between their attributes.

Objects, in the context of this document are simply the parts or components of a system and are unlimited in variety. Testing of objects consists of determining the attributes or properties of the objects. For example, the objects listed have (among others) the following attributes:

a. Switches - speed of operation, state
b. Wire - tensile strength, electrical resistance

Relationships tie the system together. The many kinds of relationships (casual, logical, random, etc.) make the "system" concept useful. For any given set of objects it is impossible to say that no interrelationships exist since, for example, for a particular physical system, one could always consider as relationships the distance between pairs of objects. The relationships to be considered in testing a given set of objects (i.e. a system test) depends primarily on the system mission, trivial or unessential relationships excluded.

If one or more components or associated system are not available for system test, it may be necessary to simulate the interfaces of these items to accomplish the test as described in MTP 6-1-002, Mathematical Model Construction and Evaluation. Regardless of the accuracy of the simulation, an uncertainty will exist as to final interface compatibility which must be considered in the technical evaluation in regard to reliability of test results.

4. SERVICE TEST

The purpose of service test is to obtain sufficient information to permit an operational evaluation and a determination of the following:

a. Degree to which the equipment meets the military characteristics (MC) and performs the mission as expressed in the QMR or SDR.
b. Suitability of the equipment and its maintenance package for use by the Army.

These determinations provide the basis for recommendations on type classification of the equipment.

The approach employed in service test of electronic equipment is basically a subjective approach which includes the planning for collection of military characteristic data under simulated or actual field conditions. The test is characterized by qualitative observation and evaluation of operational equipment by selected military personnel having a background of field experience with the type of equipment undergoing test. Instrumentation is limited to measurements of those characteristics which have major operational significance.

5. ENVIRONMENTAL TEST

The purpose of environmental test, which forms an integral part of engineering and service test, is to obtain sufficient information to determine whether the test item performs effectively in the environments of its intended use.

The approach employed in environmental test of electronic equipment is consistent with that of the overall engineering or service test. Testing

in simulated climatic extremes, such as provided by environmental test chambers, is accomplished to the maximum extent in the engineering and prior test phases. Testing in extreme natural climatic environments is used to substantiate or supplement data obtained from simulated tests.

6. INSTRUMENTATION TECHNIQUES

In the course of development testing of communications, surveillance and electronic equipment a wide-range of instrumentation is generally required. These can be classified in terms of the fundamental technology upon which it is based to include but not limited to the following:

a. Electronic
b. Electromechanical
c. Photographic
d. Optical

Instrumentation provides the primary physical means for obtaining data on equipment and environmental characteristics. For example, this applies to the measurement of such fundamental parameters of electronic signals as voltage (field intensity), current, power, waveform (modulation), frequency, period, phase, and such equipment characteristics which operate on the signal as directivity, gain, impedance, sensitivity (noise figure), selectivity (bandwidth), linearity, time constants, attenuation and correlation.

Once characteristic parameters and criteria are established, the next step is the choice of a method of measurement. This choice, made in consideration of available instrumentation, must take into account required accuracy among other factors. Indirect measurement data must be reducible to final data (variable or parameter) by data reduction equations or relationships.

Not only must the method be considered but also the details of procedure must be carefully planned. The same method and instrumentation may be used by two test personnel, yet one may obtain better results, the difference being in the care with which small disturbing factors are eliminated. It is often possible to plan the procedure so that shortcomings in the instrumentation or stray effects will balance out in the final data.

One of the basic principles in the description and analysis of measured data is that of randomization. Actual data are imagined to be a random selection, one for each measurement, of values from a large reference distribution which could be generated by infinite repetition of the test. In statistical terms, this is a finite sample from a population distribution. For reasons of mathematical convenience, it is usual to assume that the population distribution can be approximated satisfactorily by an analytic function (distribution function) having two or three parameters. A finite data sample permits at most the assignment of confidence levels to the values of the distribution function parameters which represent the best value and the significance of the measurement. Description of measured data is covered in greater detail in MTP 3-1-002, Confidence Intervals and Sample Size.

Sound instrumentation selection dicates that the test engineer be thoroughly familiar with the basic principles underlying the measurement methods and the instrumentations utilized. In the final analysis, the choice of any particular method is restricted by the availability of suitable instrumentation.

The capability to apply instrumentation is not sufficient in itself. In order to provide universal application, measurements must be based upon internationally accepted standards. Moreover, measuring instruments must be frequently calibrated against these standards.

7. GENERAL TEST DESIGN CONSIDERATIONS

Once the significant characteristics and the means for measuring or describing them (directly or indirectly) have been determined, a statistical analysis and design can be developed to permit the required analysis or evaluation in accord with test objectives. These may be categorized as follows:

a. Comparison between the standard QMR or SDR requirements and equipment performance as determined, that is, the accomplishment of the characteristic or function and the degree of such accomplishment.
b. Comparison between two different configurations of the same equipment, or between two equipments tested under similar conditions where one may be the control item.
c. Correlations among variables.

In testing, an independent variable, usually the input signal, is the factor which is varied. Dependent variables or outputs are generally equated with the equipment or system response.

In laboratory tests all the variables except one affecting equipment performance may be controlled experimentally, that is, by holding them constant or by varying such extraneous variables systematically. These include the variables due to environmental factors which can be simulated in various environmental test chambers.

In field tests, such as those required for radar systems, it is usually more difficult to control input/output relationships. The multivariate nature of the system operation may require a type of statistical treatment such as multivariate analysis in which control can be exercised statistically. For field tests, environmental factors or complete weather information must be recorded on an "as-tested" basis.

Two major factors which determine the selection of a statistical design are as follows:

a. The amount of pretest control available.
b. The number of variables whose relationship must be determined.

Statistical design can be roughly categorized as either comparative

or correlational, bivariate or multivariate. For example, comparative bivariate statistics include Student's "t" and analysis of variance. Comparative multivariate statistics include the many variation of factorial analysis of variance and analysis of co-variance. An example of a correlational bivariate technique is the Pearson "r". Correlational multivariate techniques include multiple regression analysis or partial correlation. These statistical techniques are described in greater detail in References 6 through 8.

If multivariate techniques cannot provide the degree of test control such as in tests of large electronic systems, then the approach described in MTP 6-1-002, Mathematical Model Construction and Evaluation in conjunction with engineering test can provide another means of assessing the relationships among many variables.

In summary, the factors to be considered in the overall design of a test include the following:

a. Documentation such as test directive, QMR, SDR, TC, design requirements, and previous test data.
b. Test objective.
c. Equipment characteristics or operations to be measured or described.
d. Test constraints or limitations.
e. Test variables and measures (including human operator, as applicable).
f. Instrumentation.
g Statistical analysis and design.
h. Data reduction techniques.
i. Test facility (including extreme natural environments).
j. Equipment operators.

Results of engineering and service tests are reported in test reports in accordance with the test directive and appropriate Test and Evaluation Command formats.

8. USATECOM MATERIEL TEST PROCEDURES

The USATECOM Materiel Test Procedures of which this document is a part are a collection of documents that define those test procedures utilized by the U. S. Army Test and Evaluation Command in the Engineering and Service testing of Army materiel.

The USATECOM Materiel Test Procedures are being designed specifically to accomplish the following objectives:

a. Provide a definitive document that describes existing test procedures for utilization in the preparation of Test Directives, Test Plans, and Test Reports, and in the conduct of test operations.
b. Provide a uniform testing procedure to insure comparability of tests conducted upon the same commodity item at different test activities, or by the same activity at different times.

c. Provide Headquarters, USATECOM with an up-to-date statement of current testing procedures so that the procedures may be reviewed for adequacy in term of the existing state of the art.

d. Provide Headquarters, USATECOM with a standard for the direction of the improvement effort of test procedures.

e. Reduce the time required for the preparation, review, and processing of Test Plans.

f. Provide developing agencies and military contractors with a detailed knowledge of Engineering and Service Test requirements in order to facilitate coordinated test planning.

g. Serve as a guide for developing agencies and military contractors conducting tests on military commodities.

It is to be emphasized that the Materiel Test Procedures are a guide to current testing technology and are not regularatory in nature. In those cases where unusual test requirements exist, or where new and improved procedures have been devised, appropriate testing procedures will be used by the test activity. However, in order to accomplish the stated objectives of this program it is incumbent upon all users of these procedures to make such suggestions as required to insure the technical accuracy, adequacy, and currency of the Materiel Test Procedures.

9. TEST FACILITIES

Facilities available to support an electronic test mission are described in detail in the USAEPG Instrumentation and Test Facilities pamphlet produced by the U. S. Army Electronic Proving Ground. A digest of established field sites, laboratories and their associated work shops, communication, automatic data processing and electronic equipments includes:

a. An electromagnetic environmental test facility.
b. An electronic countermeasures vulnerability test facility.
c. A systems test facility.
d. Standards and calibration facility.
e. Tracking and surveillance sensor testing facility.
f. Data processing and reduction facility.
g. Central communications system.
h. A central timing system
i. Frequency control.
j. Data acquisition.
k. Aircraft to support tests.
l. Antenna test towers and recording equipment.
m. Free space simulation using a signal source.
n. Artillery firing ranges.
o. Sensor resolution complexes.
p. Special engineering and human factors laboratories.
q. Military support for tactical environment testing and evaluation.
r. Facilities to simultaneously conduct a number of independent test programs.

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APPENDIX A

OPERATIONAL ANALYSIS OF AN ELEMENTARY COMMUNICATIONS SYSTEM

As an example an approach to the establishment of significant system test parameters through operational analysis, Figure 1 shows a model of an elementary communication system. It contains five functions which are necessary to any communication process. Certain of these functions may become rudimentary or even vanish in particular cases. The sixth element, the noise source, is usually unavoidable and unwanted.

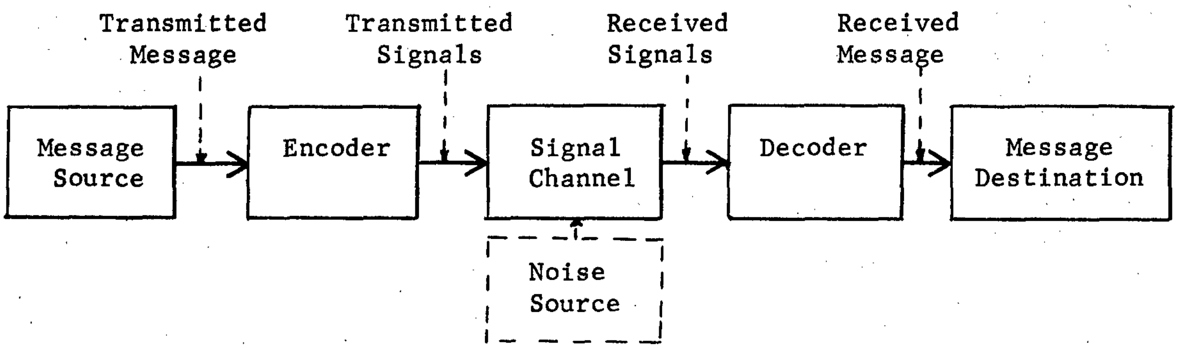

Figure 1. The Elementary Communications System

The functions of the basic system are defined as follows:

Source: The origin of the message (or sequence of messages) to be sent over the channel. It consists of a population of possible messages. Its output is the message selected from the population. Examples: a deck of punched cards, a picture or scene, a human voice.

Encoder: Operates on the message from the source and converts it to signals that the channel will accept. Its output consists of the originating signals. It is a matching device that resolves incompatibilities between the source and the channel. Examples: a microphone which converts acoustic to electric energy, a cryptographer using his codebook to encipher a message.

Signal Channel: The unique path that conveys the signals to the decoder. Some of the ways by which a particular signal channel is differentiated from all others are by space separation (use of separate wire or radio path); by frequency separation (in frequency-division multiplex systems); by time separation (in time-division multiplex systems); by electrical balance (in simplex and phantom circuits); by directions discrimination (in biconjugate circuits); or by other means (such as the polarization of a radio wave).

Decoder: Operates on the received signals and attempts to extract the message and present it in a usable form to the destination. The output of the decoder is the received message.

Destination: The recipient and utilizer of the received message.

Noise Source: Adds an interfering signal to the message signals. Noise includes thermal noise, acoustic noise, atmospheric static, power induction, crosstalk, etc. There are actually noise sources in all parts of a system. The total effect of all of them, however, may be represented by an equivalent signal noise source in the signal channel. In this view, noise anywhere in the system effectively becomes a property of the channel. Two other types of noise that are important but not yet integrated with the theory are semantic noise and psychological noise. Semantic noise refers to the ambiguity inherent in some messages, such as those encoded in the English language. Psychological and psychophysical noise may refer to several phenomena, one source arises from various thresholds of perception to physical and psychological stimuli.

For a communication system to be of any value, at least part of the information contained in the initial message must be received at the destination. But it may be altered in one or more ways. It may be changed in form, added to, subtracted from, or delayed in time with respect to the original message.

Thus in any practical communication system a source can be identified that generates the message, a destination that receives it, and a channel that transmits it. Without scrutinizing the composition of these functions, the sources can be described in terms of the properties of the messages it can generate, the destination in terms of the properties of the messages acceptable to it, and the channel in terms of the properties of the signals it can accept and deliver. Transducers are required between source and channel if their respective properties are incompatible, and similarly between channel and destination.